Forest Use Strategies and their Determinants among Rural Households in the Miombo Woodlands of the Copperbelt Province, Zambia

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1. Introduction

Forests are renewable resources and how they contribute to human well-being depends on social management and natural resilience (FAO, 2005; Herdiansyah et al., 2014). Despite the importance of forests, especially to rural households in tropical and sub-tropical countries, they are often under threat by ongoing landscape changes (Keenan et al., 2015). Changes are triggered by proximate and underlying factors which include mainly agriculture and markets (Babigumira et al., 2014); fuelwood production (Kiruki et al., 2017); demographic factors (Handavu et al., 2019); conservation interventions (Saw and Kanzaki, 2015), and evolving pressures and opportunities (Jiao et al., 2017). Increasingly changes, mostly observed in tropical and subtropical countries (Sloan and Sayer, 2015), have attracted scholarly attention (Babigumira et al., 2014; Rasmussen et al., 2017). Forest landscape dynamics are also core themes with government and forested landscape policy think-tanks such as UNFCC conference of parties (COP), and the reduction of emissions from deforestation and forest degradation (REDD+) policies (Angelsen and Rudel, 2013; Day et al., 2014; Krishnaswamy and Hanson, 1999). Forest landscape changes align with global forest use and the management discourse that underline the significance of conservation policies promoting ecosystem services relating to rural livelihoods (Kalonga and Kulindwa, 2017; Stickler et al., 2017; Wunder et al., 2014).

In the tropics, where about 800 million people continue to derive livelihoods from forests and woodlands (Chomitz et al., 2007), the diverse use of forest products can in some cases form an essential livelihood strategy (Angelsen et al., 2014; Jones et al., 2016; Khundi et al., 2011). Nonetheless, recent forest and livelihood studies have often concentrated on the overall contribution of forest products to households, without explicitly categorising households on the basis of forest product use and cash needs despite possible synergies and trade-offs between forest subsistence and cash outcomes (Ali and Rahut, 2018; Dokken and Angelsen, 2015; Nguyen et al., 2015; Porro et al., 2015; Torres et al., 2018).

Forest products are collected mainly for household subsistence purposes in the most rural areas of the tropical countries (Dewees et al., 2010; Dokken and Angelsen, 2015; Langat et al., 2016), although some households also engage in collection for commercial purposes (Jones et al., 2016; Smith et al., 2017). Other studies highlighting the contribution of forest products to households have shown the importance of various forest products to the subsistence and cash needs of rural households (Angelsen et al., 2014; Belcher et al., 2015; Kalaba et al., 2013a; Shackleton et al., 2008). However, these studies do not explain the role forest products play in forest use strategies in rural households.

Although forests support millions of people who live primarily in tropical and sub-tropical forests and woodlands (Chomitz et al., 2007; Dokken and Angelsen, 2015), the contribution of forests to rural households is threatened by unsustainable exploitation methods. Often due to the clearing of land for agriculture (Gibbs et al., 2010), and demand for fuelwood in urban areas (Baumert et al., 2016; Zulu and Richardson, 2013). For example, the growth of small towns and cities in the Copperbelt province of Zambia has put pressure on the Miombo's Mwekera and Katanino forest reserves (CSO, 2012; Handavu et al., 2019; Kalaba et al., 2013a). The growing population accelerates pressure on the forests without a corresponding growth in household wealth; this leads to unsustainable forestland exploitation for fuelwood and agriculture (Leblois et al., 2017; Tembo et al., 2015). In general, this results in deforestation (Syampungani et al., 2009), and degradation of the forests (Sedano et al., 2016; Sulaiman et al., 2017). It is, therefore, essential to better understand household dependencies on forests, based on forest products harvested and consumed, but also to understand local perspectives providing context and a frame of reference for those forested landscapes (Shriar, 2014).

In Zambia's Copperbelt province, households show significant differences in how they use and benefit from forest product harvesting (Mulenga et al., 2017; Mulenga et al., 2014). The use of forest products is related to households' subsistence and cash tendencies (Kalaba et al., 2013a; Mulenga et al., 2014), but also driven by shocks and stresses (Kalaba et al., 2013b). Subsistence and cash benefits derived from forest product use may depend on emerging opportunities and household capital endowment, including human and social capital (Handavu et al., 2019), physical and financial capital (Bwalya, 2011; Mulenga et al., 2017), and other assets such as infrastructure, power, and institutions (Wolfersberger et al., 2015). On the other hand, external pressures present an ever-increasing demand for forest products, mainly in the form of the

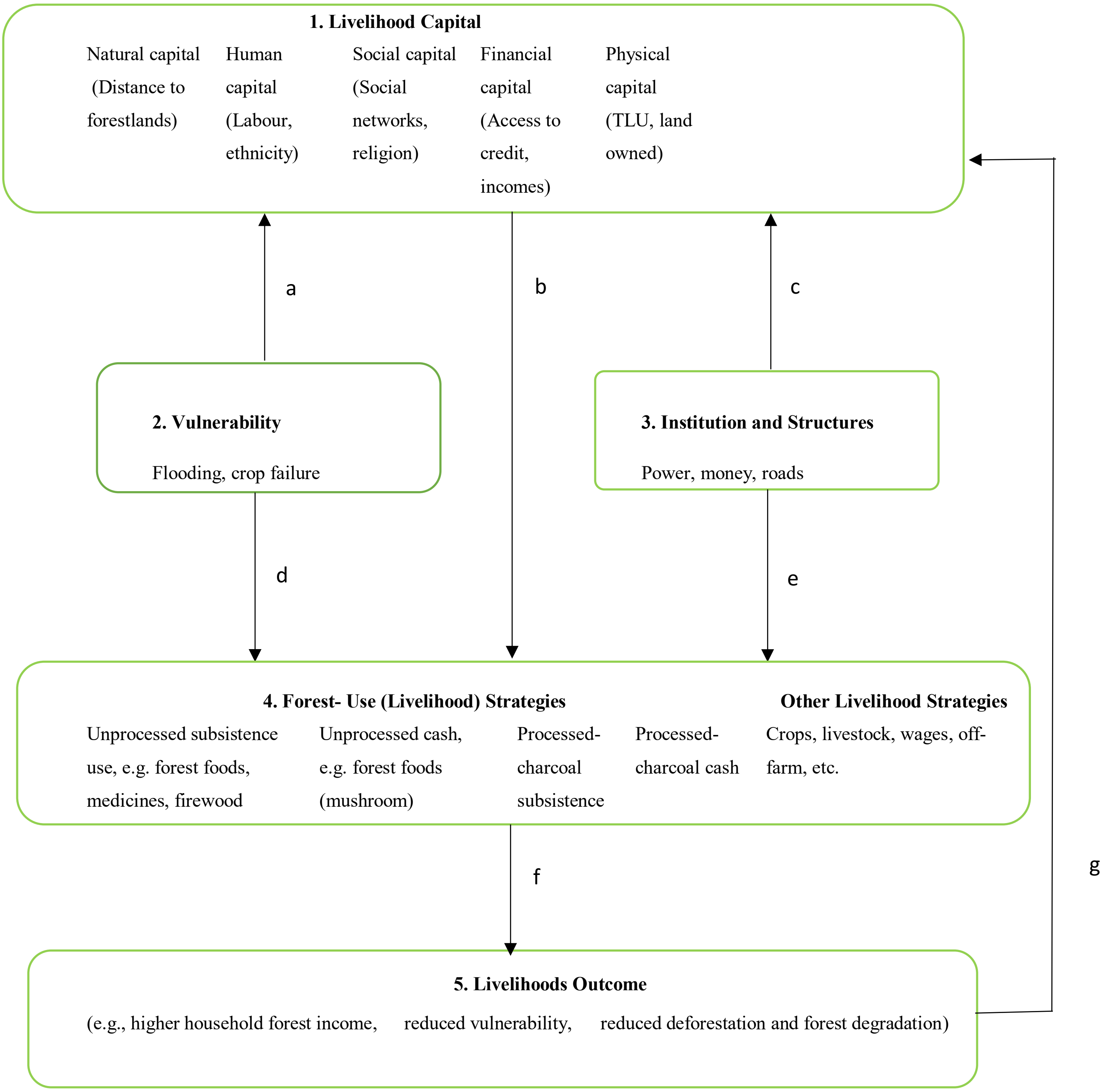
urban demand for cheap energy (Tembo et al., 2015; Zulu and Richardson, 2013) and forest food (DeFries et al., 2010; Rowland et al., 2017).
Studies on forest use and livelihoods can often be limited to describing activities that represent a combination of livelihood strategies such as agriculture or characterised as low-skilled and highly-skilled livelihood strategies (Angelsen et al., 2014; Nguyen et al., 2015; Soltani et al., 2012). Yet generalising activities that contribute to rural livelihoods eventually results in a lack of understanding of the livelihood contribution of the various forest products, especially to rural people living within or close to the forests (Sunderland et al., 2017).

There are limited quantitative empirical studies that have attempted to show a diverse picture of how households use forest products, especially for forested landscapes in Zambia. Categorising households based on their forest product use provides an understanding of forest-based livelihood strategies (forest use strategies) among people inhabiting in the Miombo woodlands (Dewees et al., 2010); this is especially important for Zambia because forests occupy about 66% of its land area (Kalinda et al., 2013) and offer livelihoods to most rural inhabitants (Chidumayo and Gumbo, 2010; Jumbe et al., 2008; Kalaba et al., 2013a; Mulenga et al., 2014). Categorising households based on their forest product use provides a more comprehensive picture of use strategies among rural households in Miombo woodland landscapes, which is important for targeted policy action (Wunder et al., 2014). In this study, we have taken a three-way approach to understanding the role of the forest products in the household forest use strategies, evaluating factors that affect forest use strategy choices. Firstly, the study seeks to define forest use strategies by establishing forest products and their monetary values in Copperbelt rural areas. Secondly, the study identifies the factors that affect each forest use strategy with a specific focus on the five capitals: natural, human, social, economic and physical. Thirdly, we analyse forest income across distinct forest use strategies.

2. Conceptual Framework

2.1. Forest Use Strategy Choices of Rural Households

In recent years, both scholars and development practitioners have applied and used a Sustainable Livelihood Approach (SLA) to understand livelihood strategies for rural households (Ashley and Carney, 1999; Scoones, 1998). Recent studies on forests and livelihoods have applied SLA to understand rural livelihoods, their linkages with factors shaping rural household behaviour that rely on natural resources in tropical countries (Babulo et al., 2008; Nguyen et al., 2015; Soltani et al., 2012). Our study draws on the broader "livelihoods conceptual framework" (Ashley and Carney, 1999; Scoones, 1998) to describe forest use strategy choices among households in the Copperbelt Province of Zambia. Chambers and Conway (1992) describe a livelihood strategy as the "capabilities, assets and activities required for a livelihood." A conceptual framework for livelihoods constitutes livelihood capital, livelihood strategies and livelihood outcomes (Fig.1). The livelihood capital provides the basis for how households make livelihood choices. The capital can either be based on natural capital, such as forests, water, and agricultural land, or household capital consisting of human, social, financial and physical capital (Babulo et al., 2008; Nguyen et al., 2015). Based on the capabilities and endowments of the household, as well the prevailing opportunities, a household will use a combination of livelihood capital to either diversify for subsistence or engage in production for cash generation (Jones et al., 2016; Kalaba et al., 2013a; Mwitwa and Makano, 2012). Livelihood strategies, however, are also affected by factors beyond household control, such as shocks and infrastructure (Angelsen et al., 2014). For example, shocks affect capital, flooding affects road access, and livestock disease outbreaks affect animal assets. Thus, any choice of livelihood strategy selected by the household results in the desired set of livelihood categories, such as a high income (Nielsen et al., 2012) or a high capacity to cope with shock (Kalaba et al., 2013b), which, in turn, affect some livelihood capitals. For example, investments into capital assets or the education of household members.



The arrows show the direction of influence, e.g. Arrow B shows that livelihood capitals (Box 1) influence forest strategies (Box 4).

Fig. 1. A conceptual framework for the analysis of forest use (livelihood) strategy choices. *Source:* Modified from Ashley and Carney (1999) and Scoones (1998)

2.2. Forest Use Strategy Choices in the Miombo Woodlands of Zambia

The Miombo woodlands occupy about 45% of Zambia's forestland (Kalinda et al., 2013) and are a major source of livelihood for rural households (Kalaba et al., 2013a; Mulenga et al., 2014). The Miombo woodlands provide a wealth of species diversity (Frost et al., 2003), and a range of extractive products (Chinsembu, 2016; Handavu et al., 2019; Syampungani et al., 2009) to its inhabitants. It is estimated that the Miombo woodlands' contributions to total household income for households range from 35 to 43.9% (Kalaba et al., 2013a; Mulenga et al., 2014).

The Miombo products are consumed either in unprocessed or processed form. Unprocessed products form the bulk of household consumption needs, meaning subsistence use of forest products; these include wild plants, fruits, edible insects, honey, mushrooms, roots, tubers, and edible leaves (Handavu et al., 2019; Shackleton et al., 2010). Despite the low monetary value of subsistence forest products, their contribution to food security for households underlines their importance among rural households in Zambia. On the other hand, processed forest products including charcoal (Jones et al., 2016; Tembo et al., 2015), and timber and bark products, such as medicinal plants, are primarily processed for cash generation in households (Banda et al., 2007; Campbell et al., 2008; Chinsembu, 2016; Chungu et al., 2007).

The Miombo forest products are mainly harvested from public forestlands that include forest reserves (Kalinda et al., 2008), and private forests (exclusively owned forestlands) (Chitonge et al., 2017). Given that use of forest resources is entwined in most people's culture (Chidumayo and Gumbo, 2010; Syampungani et al., 2016), there is a high reliance on forest products the Miombo woodlands (Dewees et al., 2010; Kalaba et al., 2013a). However, high deforestation rates estimated at 0.5–0.6% of total forest cover (i.e. 250,000–300,000 ha/year) (FAO, 2015), and forest degradation threaten the Miombo's integrity and consequently its provisional ability (Chidumayo, 2013; Syampungani et al., 2009). Forest product assessments offer us the means to assess the quantitative contribution of the forest products to rural livelihoods, but also to understand the volume of forest products that households extract from forest landscapes.

3. Material and Methods

3.1. Study Area

The Copperbelt Province is one of ten provinces in Zambia (CSO, 2012) (Fig. 2) and is situated on the Central African plateau, also known as the Miombo woodlands. The province is located at an average elevation of 1,200 meters above sea level and receives an annual rainfall of about 1,200 mm, with temperatures ranging from 17°C to 31°C (MTNER, 2010). These climatic conditions give rise to three distinct seasons in the Copperbelt. The hot-wet season is from December to April; the cold-dry season from May to August; and the hot-dry season from September to November (Syampungani et al., 2010). The Copperbelt province covers a total area of 31,328 square kilometres (km^2), representing about 4.2% of Zambia's total area (CSO, 2014). The Central Statistics Office (CSO) (2012), estimates the population of the Copperbelt Province at 1,972,317 people of which 376,861 live in the rural areas and deriving livelihoods from the Miombo woodlands (Handavu et al., 2019; Kalaba et al., 2013a).

The Miombo woodlands are characterised by a high abundance of trees of the genera *Brachystegia*, *Julbernadia*, and *Isoberlinia* (Timberlake et al., 2010), which mainly provide wood for the production of charcoal (Kalaba et al., 2013c). The main charcoal species preferred by Miombo inhabitants are *Isoberlinia angolensis*, *Julbernadia paniculata*, *Brachystegia boehmii, Brachystegia floribunda,* and *Parinari curatellifolia*. Except for *Parinari curatellifolia*, all charcoal species are used for firewood (Syampungani, 2009). Despite differences in the use of Miombo forest resources, charcoal and firewood species in Miombo are prevalent throughout Zambian forest landscapes (Kalinda et al., 2013). In the Copperbelt province, 1.89 million hectares of land is under forest cover. This province has the highest relative tree cover loss, estimated at 14% compared to the Luapula province (10%), the Western (9.4%), the Central (8.6%), and the Eastern province (5.6%). These form the top four regions responsible for about 52% of all tree cover loss in Zambia between 2001 and 2018 (Curtis et al., 2018; Hansen et al., 2013). Tree cover loss in the Copperbelt province is mainly influenced by clearing of land for agriculture, degazzetion of forest areas, charcoal production and urbanisation (MTNER, 2009; Tembo et al., 2015; Vinya et al., 2011). For example, Kalaba et al. (2013) observed a high use of forest resources from the Katanino and Mwekera forest reserves in the Copperbelt while Mulenga et al. (2015) noted that about 16% of households in the Copperbelt province engaged in charcoal production, compared to other provinces which were estimated to be between 3 and 12%.

Administratively, part of the Copperbelt forest is traditionally or formally managed, and elsewhere is under unknown management (Kalinda et al., 2013). The forestlands are maintained in a dual system which recognises customary and state ownership of land (Chanock, 1985; Kalinda et al., 2008). These traditional structures and practices differ from one chiefdom to another, owing to traditional methods and practices derived over the long term (Chanock, 1985; Kalinda et al., 2008). However, in most cases, the Chief is the de facto overall administrator of all the land under his jurisdiction and often appoints the Sub-Chief (*Induna*) and the Head of the Village responsibility too (Chitonge et al., 2017). The state manages restricted forests, such as national parks, national forests and game management areas, in collaboration with the establishment of the chiefdom (GRZ, 1995).

3.1.1. Site Selection

We selected the study sites (landscapes) through a systematic process that involved a literature review, use of satellite imagery, scoping visits, and semi-structured interviews with the district officials and Sub-Chiefs. We selected four landscapes that represent the variability of forest cover and population pressure of the Copperbelt province (Fig. 2). Each landscape selected covers an area of 12 x 12 km^2, and represents different regimes of restriction and non-restriction to access and use of forest resources (Table 1). The four landscapes selected include Shibuchinga and Lumpuma chiefdom in Luwanyama, and Mushili and Nkambo chiefdom Masaiti district; these chiefdoms form the administrative units to which the forestlands belong. Some of the forestlands, such as national parks, national forests, and game management areas, are under state authority, thus restricted from use. On the other hand, the non-restricted forestlands, such as communal lands, inherited and privately allocated landholdings, are administered based on local customs and traditions (Mulenga et al., 2015). Land in customary areas is, in most cases, managed by a single person on behalf of the group while the Chief's role is to regulate acquisition and land-use (Chileshe, 2005; Payne and Durand-Lasserve, 2012). Although there is a mixture of forestlands, each landscape has been categorised by the extent of the two types of regimes, with each arrangement being managed by one chiefdom (GRZ, 1995) (Fig. 2). Furthermore, in each landscape, we selected 3–4 village clusters (villages) and compiled a list of households for the selected villages.

Table 1.

Spatial Characteristics of the Four Landscapes in the Study Area.

District	Chiefdom-landscape	Restriction in use	[1]Forest Reserve	[2]Total area [km^2]	[3]Restricted area [km^2]	[4]Forest ('TA') 2016 [km^2]	[5]Forest ('TA') restricted 2016 [km^2]	[6]Roads [km] ([km/km^2])	[7]Population [pers.] ([pers./km^2]) 2015
Lufwanyama	Shibuchinga	Non-restricted	-	142.59	-	86.87 (60.92%)	-	42.78 (0.30)	950 (6.66)
Lufwanyama	Lumpuma	Restricted	Lamba block C	144.45	47.68 (33.01%)	81.04 (56.10%)	28.20 (34.80%)	40.45 (0.28)	861 (5.96)
Masaiti	Nkambo	Restricted	Miengwe	139.70	35.29 (25.26%)	73.72 (52.77%)	33.71 (45.73%)	135.51 (0.97)	2,358 (16.88)
Masaiti	Mushili	Non-restricted	-	139.18	-	55.74 (40.05%)	-	144.75 (1.04)	1,880 (13.51)

1 - Name of the forest reserve (IUCN and UNEP-WCMC, 2016).
2 - Total area of the landscape (no buffer included).
3 - The percentage of protected area within the landscape (IUCN and UNEP-WCMC, 2016).
4 - Area of tree-cover vegetation (i.e. tree-cover areas (TA) in the landscape. The percentage represents TA compared to the total area of the landscape (ESA, 2017).
5 - The percentage of restricted forest (i.e. protected TA) compared to the total forest area in the landscape (ESA, 2017).
6 - Estimated road density existing within the landscape area is calculated with a 5km buffer. The total roads in km were extrapolated within landscape boundaries (OpenStreetsMap, 2019) and (self-digitisation).
7 - The total number of inhabitants was extrapolated within landscape boundaries, and estimated population density calculated with a 5 km buffer (Linard et al., 2012).

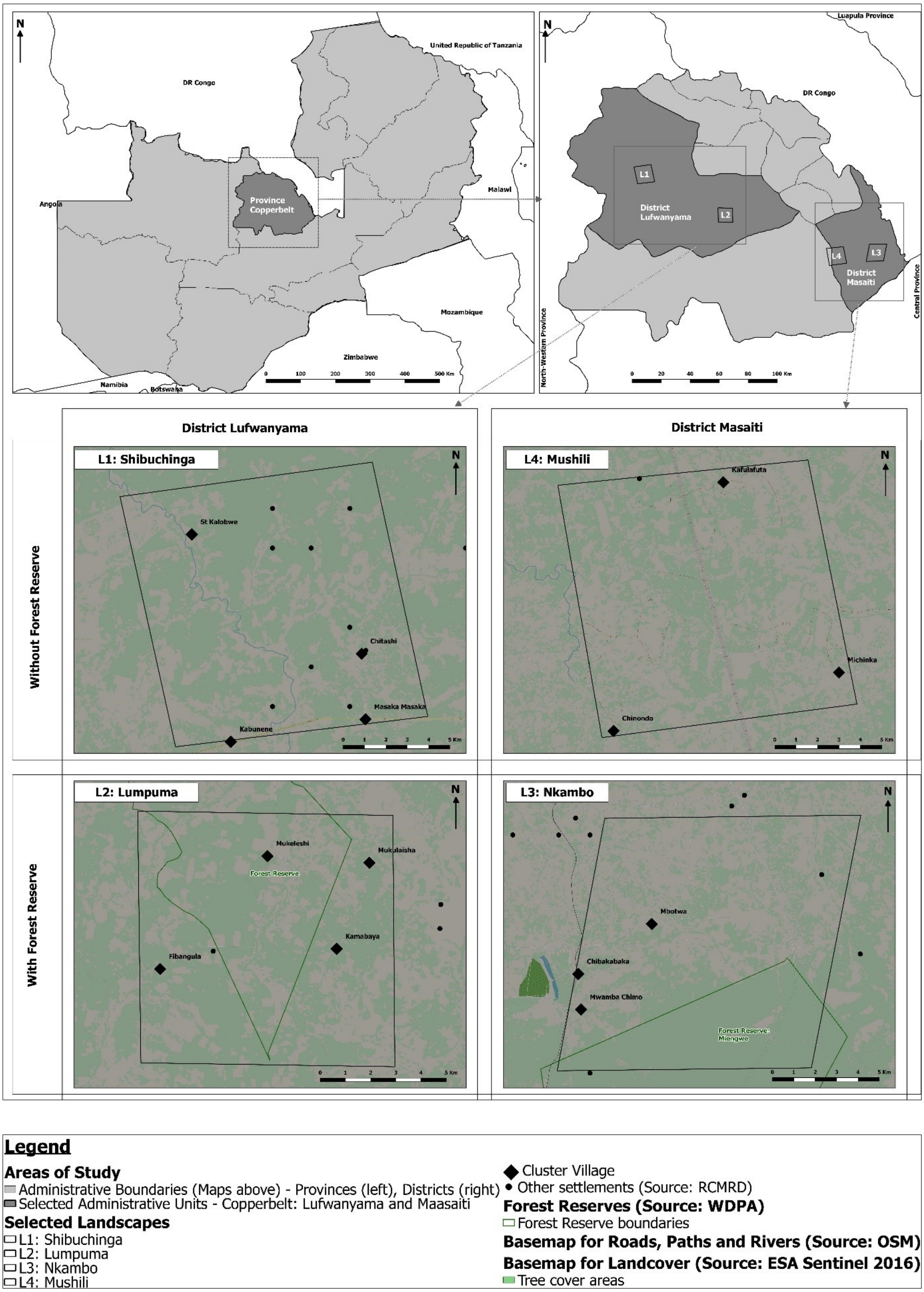


Fig. 2. Map of Zambia (top-left), Copperbelt Province (top-right), and study landscapes (below) in Lufwanyama and Masaiti district.

3.2. Data Collection

3.2.1. Household Survey

The study conducted a household survey to capture information on the composition and demographics of households, land-use and assets, production and economic activities (farming, livestock and fisheries, off-farm and non-farm income), forest use, forest user groups, and forest policy instruments. We interviewed the key informants who were identified through a snowball method with village leaders and other persons considered knowledgeable in order to delineate villages, understand village structures, and the number of households that were available per village.

A sample size of 100 households was determined a priori for each landscape; this was the study's standard sample size for all landscapes. However, the number of households for which the sample size in each landscape was drawn ranged from 260 to 372 households. We used a random sampling method to select respondent households. We chose a simple random method to increase efficiency and reduce variance between samples (De Leeuw et al., 2012). To further minimise sample errors from non-response and absentee households, we selected five additional households in each village (if the originally selected households were not available). In conducting a random selection of households, we subsequently assigned distinctive numbers to households in the generated household roster; then the roster containing household numbers was shredded, folded, and put in a bowl/hat. We mixed the bowl's contents, and households were then selected randomly in a joint exercise by the researchers, a few village members and village leaders. The selection exercise was repeated several times until we achieved the assigned number of households for each village, and the method was replicated for all the study sites.

The study collected household data using a structured questionnaire administered by the research assistants. The main respondent was the head of the household, or alternately, any other adult person who had been living with the household for at least one year and was familiar with households' livelihood assets and land-use decisions. The study conducted household interviews in the local language; in the Copperbelt, primarily Bemba and Lamba. Household interviews lasted about an hour and thirty minutes. The interviews were conducted following guidelines for household interviews recommended by Angelsen (2011) for measuring livelihoods and environmental dependence. We asked about the quantity of crop production, livestock and forest products consumed and sold for the last twelve months. Given the restriction on harvesting certain forest products, such as the production of charcoal, hunting and other woody materials in restricted forest areas or any forest area (Forests Act, 2015), some operations are illegal and may be underreported in the household survey. This research cannot test or control this prospective bias in our data. However, we tried to limit any bias that would accrue during the data collection stage that involved scoping visits and household data collection. The study emphasised its neutrality at the hiring of the research assistants, and underscored to village leaders and households that our research group is not government associated. Finally, the research surveyed 412 households within the four landscapes selected in the Copperbelt province.

3.2.2. Household Characteristics

In a particular setting, socio-economic and environmental factors influence household behaviour. Understanding the characteristics of households is an important step in analysing the livelihood choices of households, particularly forest use strategy choices (Angelsen et al., 2014). We assessed the characteristics of households such as forest access, market access, demographics and land-use patterns (Babigumira et al., 2014; Handavu et al., 2019; Mulenga et al., 2014), also see Appendix A (Table A1).

3.2.3. The Volume of Firewood Collected and Charcoal Produced

The volume equivalents produced for charcoal and firewood extracted in the study area were used to estimate the quantity of wood biomass extracted in the Miombo woodlands. The study randomly measured actual dry weights of firewood (headload) bundle, and charcoal (50-bag kg) in the different villages. Each product was weighed five times and the average weight calculated. For approximately 32 kg of charcoal produced in an earth kiln (Chidumayo, 1993), we applied a conversion factor of 9m^3 per tonne (FAO, 1987), while for 23 kg (headload) of firewood, we applied a factor of 0.33m^3 per tonne (Openshaw, 1983). The volume conversion enables a standard estimation of per capita consumption of firewood and charcoal in our study sites.

3.2.4. Calculating Forest Income

Our study captured real and perceived forest product prices through household interviews, village market surveys, and key informant interviews. We analysed the initial findings of the study to establish a list of forest products harvested by households. Later, we performed a separate price study to capture the perceived prices of some forest products that had no market value. The price survey targeted key forest product producers in the village markets and also performed group interviews with merchants at particular village markets. We surveyed five respondents from each village, selected via a two-step method involving consulting with village officials to identify initial participants and subsequently using a snowball method.

Forest income values were calculated as net income as defined in most environmental income studies (Angelsen et al., 2014; Dokken and Angelsen, 2015). Forest net income means subsistence or cash income from forest products minus the value of hired labour, marketing and transportation costs. As in previous studies, the value of own labour is not deducted from net income because it is not possible to establish suitable shadow labour prices in rural areas (Cavendish, 2012; Luckert and Campbell, 2012). Furthermore, forest income is adjusted to account for varying household size and composition (Handavu et al., 2019). We estimated the net forest income variable in adult equivalent units (AEU) (i.e. Kwacha/AEU); where adults aged between 15 and 64 are assigned a weight of one (1), and dependants below 15 and above 64 are assigned a weight of 0.5 (Dokken and Angelsen, 2015). Other variables, such as exclusively owned forestland (i.e. the household exclusively owns the forestland which includes both used and unused land) were also converted to AEU (ha/AEU) see Appendix A (Table A1).

3.3. Econometric Model and Estimation

3.3.1. Determining Forest Use Strategy Choices

To determine the forest use strategy choices which households adopted in the Copperbelt Province, we applied a cluster analysis on subsistence and the cash income derived from harvesting unprocessed and processed forest products. Through our study design, all households in the study sites had access to forestland (whether used exclusively or publicly or both), and we observed that all households used forest products in one way or the other. The differences in forest product use arise from the types and quantities of the products harvested, and the frequency with which each product is used. Based on the household's use of forest products, the clustering method assisted in categorising households into forest use strategies. Clustering households based on forest products, rather than all rural livelihood sources, enables a differentiated examination of forest-based livelihoods.

This study specifically applied k-means clustering on variables that represent value in the use of forest products. The k-means cluster algorithm is a partitional clustering method commonly used as an exploratory clustering technique (Hastie et al., 2005). When the number of clusters is unknown, several k-means solutions with a different number of groups k (k = 1,…, K) are computed and compared (Makles, 2012). By applying the k-means algorithm on the total forest income, processed subsistence and forest cash income, and unprocessed subsistence and forest cash income, we are able to detect the clustering with the optimal number of groups, k from the set of K solutions. We used a scree plot and searched for a kink in the curve generated from within the sum of squares (WSS) (Makles, 2012). We chose the k-means clustering because of its ability to scale each column while minimising variability within clusters and maximising variability between clusters (Brown et al., 2006; Nguyen et al., 2015; Var, 1998). It can be applied in numerical data measured on the same units, and also data whose variables are captured in different units of measurement, thus helping to correct errors that could happen between different clusters (Soltani et al., 2012). Once the clustering was complete, a one-way ANOVA was performed on the results to make sure that the means in the independently categorised household clusters are different. While the chi-square (X^2) was performed to ensure that at least two clusters were statistically different (Dattalo, 2013).

3.3.2. Estimating the Determinants of Forest Use Strategy Choices

Forest use strategies adopted by households, were identified by the categories determined by the cluster outcomes on forest income. The forest use strategy choices formed the basis for the Multinomial Logistic regression (MNL). The MNL is applied when the dependent variable is unordered and consists of multiple categories (Wooldridge, 2010). In our analysis, the cluster categories are independent of each other, implying that membership in one category is not related to the membership of another category. However, the categories cannot be perfectly separated, and are non-linearly related to independent variables; such relations are best analysed using MNL regression (Starkweather and Moske, 2011). Before performing the MNL, we checked for Multicollinearity using the Variance Inflation Factor (VIF) for all the independent variables, as shown in Appendix A (Table A1). And while performing the MNL, we used manual step-by-step elimination (Dattalo, 2013) of variables that showed p>0.5 in both cluster categories.

Thus, our theoretical MNL model follows the framing as applied by Dehghani Pour et al. (2018):

$$\eta_{ij} = \frac{\exp(X'_j \beta_j)}{\sum_{i=1}^{m} \exp(X'_i \beta_i)}, \; j = 1,2 \dots, m$$

Where η_{ij} is the model for the probability of household that shows that household i chooses a livelihood strategy j from m strategies, X_i is the vector for the explanatory variables associated with the i^{th} household, and β_j =0 for the baseline. Thus the coefficients are interpreted with respect to the baseline strategy and estimated by the maximum likelihood method (Wooldridge, 2010). Following the SLA, the households' livelihood strategy choices can be derived from a livelihood's capital which encompasses five capitals (Fig. 1). Table A1 in Appendix A shows the explanatory (independent) variables used to model the structural relationship between forest use strategy choices and livelihood capitals. Non-productive fixed assets, such as owning dwelling unit/s, and small equipment, such as hoes, bicycles and radios, were excluded from the analysis because they showed no variability among rural households.

The empirical model is as follows:

$$\eta_{ij} = \alpha_0 + \beta_1 dis_{for_{pub}} + \beta_2 dis_{for\_own} + \beta_3 fc_{los} + \beta_4 age + \beta_5 gender + \beta_6 hh_{size} + \beta_7 educ + \beta_8 ethnic + \beta_9 mobphone + \beta_{10} migration + \beta_{11} credit + \beta_{12} cropinc + \beta_{13} livinc + \beta_{14} off_{farm} + \beta_{15} self_{empl} + \beta_{16} remi + \beta_{17} TLU + \beta_{18} land_{owned} + \beta_{19} dis_{mainroad} + \beta_{20} access_{road} + \beta_{21} incomeshock_{crop} + \beta_{22} assetshock_{livestcok} + \beta_{23} labour_{illness} + \varepsilon_i$$

Where η_{ij} shows the probability of household i choosing strategy j, and definitions of the independent variables are given in Appendix A (Table A1).

4. Results

4.1. Descriptive Results

4.1.1. Socioeconomic and Environmental Characteristics of Households

Table 2 shows a summary of the characteristics of the households in the Miombo woodlands of the Copperbelt. The results reveal that households walked shorter distances to exclusively owned forestlands (forestland exclusively owned by households) (i.e. 1.3 km) than to public forestlands (communal areas, and state lands) (i.e. 1.9 km). A further assessment of the forestlands reveals that households in the rural Copperbelt own an average of 9.6 hectares (ha) of land translating to 2.3 ha per AEU (Table 2). These rural areas are characterised by a lack of access to permanent roads, restricted use rights of public forestlands, and longer distances to the village centres (Table 2). While other capitals, i.e. human, and social capital, reveal a patriarchal inclination, as 88% were male-headed households, and the largest group (49%) was part of the Lamba tribe. The average size of a household is 4.5 in AEU with heads of the households, mainly attaining primary level education (Table 2).

Table 2.

Characteristics of the Households in the Study Area (n=412)

Variable description	Mean ±SD*
Natural capital	
Walking distance from household to public forestland (km)	1.9±1.6
Walking distance from household to exclusively owned forestland (km)	1.3±1.3
**Forest cover loss observed by household in the last five years (1/0)	85%
Household participates in charcoal production (1/0)	50%
Human capital	
Ages of the head of household (years)	45.1±14.0
Gender of the head of the household (1-male / 0-female)	88%
Household (HH) size (number of people)	5.9±2.5
Household (HH) size - adult equivalent unit (AEU)	4.5±1.9
Head of the household education (1-high school and above / 0)	25%
Social capital	
Head of household belongs to the largest ethnic group - Lamba (1/0)	49%
Number of phones in the household (number)	1.1±1.0
Duration of residence in the village (years)	16.1±13.6
Financial capital	
***Total household income (kwacha) - per capita	5934.6±11025.7
Household accessed credit in the last one year (1/0)	20%
Physical capital	
Tropical livestock unit (TLU)	1.8±4.5
Size of land owned by household (ha)	9.6±12.6
Size of land owned by household (ha^{-AEU})	2.3±3.3
Infrastructure (exogenous)	
Access to road usable throughout the year (1/0)	33%
Household walking distance to the main road (Km)	4.2±4.9
Vulnerability (exogenous)	
Income shock-crop failure in 2017 season (1/0)	72%
Asset failure-livestock loss (1/0)	26%
Labour loss - an illness of a member of the family (1/0)	31%
Labour loss - the death of a member of the family (1/0)	12%

*SD is the standard deviation. **Miombo is reported to have high woodland recovery after felling (Chidumayo, 2004; Syampungani et al., 2016). ***Income is measured in net value and analysed in relation to adult equivalent (AEU) per capita as applied by Dokken and Angelsen (2015). All income values are calculated in Zambian Kwacha (ZMW). At the time of the study, 1 USD = 10.13 ZMW (Bank of Zambia, 2018). One household has a negative total household income; this could have been because of high production costs and crop failure, or livestock loss, this household is not included in the descriptive analysis and subsequent calculations that follow. The sample size is, therefore reduced from 413 to 412 households.

4.1.2. Description of Households' Income Sources

The study also analyses the relative contribution of various income sources to total households' income (share of income attributed to different sources) (Table 3). The relative contribution of forest income to households is analysed and discussed in relation to other rural household income sources. Forest products (i.e. unprocessed and processed) by far contributed the largest share of household income (54.1%) compared to other rural income sources. Processed products, mostly charcoal, accounted for 37.4% of total household income in the rural Copperbelt (Table 3). On the other hand, agricultural income (crops, livestock and fish) contributed to 33% of the share of total household income, while crop production is the second highest income source contributing 23.4% of the share of the total income in the rural Copperbelt (Table 3). Unlike forest products and agriculture, the contribution of other income sources to households' total income was low and estimated at 12.9% (Table 3).

Table 3.

Distribution of Household Income by Source in the Study Area (n=412)

*Income sources (Zambian kwacha) (ZMW)	Mean ±SD	Share of total sample income (%)
Unprocessed forest product income	994±1259	16.7
Processed forest product income	2222±8272	37.4
Subtotal: Forest products income		**54.1**
Crop income	1390±4670	23.4
Livestock income	563±1261	9.5
Fish income	8±26	0.1
Subtotal: Agriculture income		**33.0**
Off-farm income	39±189	0.7
Self-employment	515±3575	8.7
Remittances income	71±312	1.2
Wage income	133±664	2.3
Subtotal: Other incomes		**12.9**
Total household income	**5935±11026**	**100**

*Income is measured in net value divided by the AEU and is calculated in Zambian Kwacha (ZMW) per capita. At the time of the study, 1 USD = 10.13 ZMW (Bank of Zambia, 2018).

The contribution of processed and unprocessed forest products to household cash and subsistence needs are presented in Table 4. Processed forest products provided higher forest income (69.1%) compared to non-processed forest products. Charcoal was the most extensively processed forest product providing a higher income compared to other forest products. These results suggest that charcoal is an important economic livelihood component of charcoal processing households. Unprocessed forest products mainly contributed to subsistence needs; these products most commonly included firewood and forest foods (i.e. mushrooms, honey, beverages and wild animals) (Table 4).

Table 4.

Main Forest Products Providing Subsistence and Cash Income in the Study Area (n=412)

Variable	Processed		Unprocessed	
	Mean±SD	Share of total forest income (%)**	Mean±SD	Share of total forest income (%)**
Subsistence forest income (total)	**148.2±620.8**	**4.6**	**916.2±1187.0**	**28.5**
Charcoal subsistence income	144.4±618.4	4.5		
Forest foods subsistence income (mushrooms, fruits, beverages, honey, animals)	2.8±42.6	0.1	490.3±826.1	15.2
Structures and fibres subsistence income (poles, thatch-grass, fibre, timber)	1.0±9.7	0.0	54.2±117.0	1.7
Firewood			369.1±394.4	11.5
Medicines			1.2±5.2	0.0
Other forest products subsistence income			1.3±7.4	0.0
Cash forest income (total)	**2074.1±7800.7**	**64.5**	**77.9±275.1**	**2.4**
Charcoal income	2029.8±7786.2	63.1		
Forest foods income (mushrooms, fruits, beverages, honey, animals)	29.0±257.8	0.9	77.5±275.0	2.4
Structures and fibres cash income (poles, thatch-grass, fibre)	15.3±213.1	0.5	0.1±1.3	0.0
Firewood			0.1±1.3	0.0
Medicines			0.0±1.0	0.0
Other forest products subsistence income			0.2±1.5	0.0
Absolute value (ZMW)* **	**2222.4±8271.6**	**69.1**	**994.0±1258.6**	**30.9**

**The share of total forest income is calculated by dividing mean income per source for the whole sample, by total forest absolute value (i.e. processed plus unprocessed incomes). ***All income values are in AEU per capita and measured in Zambian Kwacha.

4.1.3. Volume Equivalents of Firewood and Charcoal

In restricted forestland landscapes, the per capita consumption of fuelwood (i.e. firewood extracted and charcoal produced) is $1.61m^3$ ($1.61m^3$/year/AEU) higher than in non-restricted landscapes (Table 5). Nevertheless, we found that in both restricted and non-restricted landscapes, higher volumes of charcoal per capita were produced relative to firewood (Table 5).

When we compare extracted volumes of firewood and charcoal produced within each landscape, the per capita volume of charcoal produced is $3.8m^3$/year/AEU, and $2.21m^3$/year/AEU higher than the per capita volume of firewood extracted in the restricted and non-restricted landscapes (Table 5). For households obtaining forest products only from exclusively owned forestlands, the per capita volume of charcoal produced in restricted ($1.75m^3$/year/ha)[a] and non-restricted ($1.06m^3$/year/ha) landscapes would be much higher than the per capita volume of firewood extracted in restricted ($0.1m^3$/year/ha) and non-restricted ($0.09m^3$/year/ha) landscapes.

Therefore, restricted landscapes of the Copperbelt provided higher per capita volumes of charcoal and firewood than non-restricted landscapes. However, the difference in per capita consumption observed across households show higher volumes of charcoal produced both in restricted and non-restricted landscapes relative to firewood. Our finding supports results from Table 3 and 4 that indicate charcoal as a forest activity of high income relative to firewood, which is mainly for subsistence purposes.

Table 5.

The Quantities of Charcoal, Firewood, and Volume Equivalents per Year per Household in the Study Area (n=412).

Description	[1]Average units collected/year /hh (restricted landscape)	Average units collected/year /hh (non-restricted)	[2] Unit	[3]Average kgs/ unit	Conversion factor (m^3/t)	[4]Volume m^3/year/hh (restricted landscape)	Volume m^3/year/hh (non-restricted)	[5]Volume m^3/year/AEU (restricted landscape)[a]	[6]Volume m^3/year/AEU (non-restricted)
Firewood	138.9 (CI, 121.7-156.1)	129.4 (CI, 114.4-144.3)	Headload (Bundle)	23±7.98	0.33	1.05	0.98	0.23	0.22
Charcoal	62.9 (CI, 47.7-78.0)	37.9 (CI, 25.4-50.4)	50-bag-kg+'ball pen'	32±3.11	9.00	18.12	10.92	4.03	2.43
Total						19.17	11.90	4.26	2.65

1. Confidence interval (CI) is taken at 95%. 2. The local unit used for measuring forest products in the study area. 3. Random weights of firewood and charcoal were taken at different locations of the study; in total, each product was weighed five times. 4. Volume per cubic metre per year per household (m^3/year/hh) is calculated by multiplying the average unit by average kgs, the result is converted to tonnes and then divided by a conversion factor (e.g. for a restricted landscape we have 138.9*23kg=3194.7kg ➔3194.7kg = 3.1947 t ➔ 3.1947*0.33= 1.054m^3/year/hh). 5, and 6. Cubic volume per year per person (AEU) (i.e. m^3/year/hh), calculated by dividing 4 by household size per AEU (4.5) (Table 2).

[a]Note, assuming firewood extraction and charcoal produced are only obtained from exclusively owned forestland, 5 and 6 would be divided by 2.3 ha (Table 2).

Source: Own calculation from household data survey (2017–2018).

4.2. Econometric Results.

4.2.1. Description of Households' Forest Use Strategy Choices

The scree plot in Appendix A (Fig. A1) shows that three k-means clusters best explain forest use strategy choices in the Copperbelt province. The three forest use strategy choices are pure subsistence-orientated forest users, specialised charcoal sellers, and forest food and charcoal sellers (Table 6). Pure subsistence-orientated forest users make up Cluster One (1), consisting of 49.5% of households in the study area. Cluster Two (2) is made up of specialised charcoal sellers and comprises of 32.3% of households in the study area. While Cluster Three (3) consists of 18.2% of households and includes forest food and charcoal sellers. Cluster One households earned a lower income from collecting forest products than Clusters Two and Three (Table 7). On the other hand, Cluster Two households earned higher income from charcoal sales than Clusters One and Three. However, there is no statistical difference between Cluster Two and Cluster Three in the amount of income from charcoal production (Table 7). Yet, Cluster Three households earned higher forest food sales income than Cluster Two households (Table 7). Clusters Two and Three are both households involved with charcoal production, which together account for up to 50.5% of study households, thus suggesting the importance of charcoal production to the rural economy, especially for the province of Copperbelt.

Table 6

Forest Livelihood Strategies in the Study Area (Cluster Analysis)

Cluster	No. of HH	Per cent (%)	Main forest-livelihood strategies
1	204	49.5	Pure subsistence forest users
2	133	32.3	Specialised charcoal sellers
3	75	18.2	Forest food and charcoal sellers
Total	**412**	**100**	

Source: Own calculation from LaForeT household data survey (2017–2018).

Table 7 illustrates the type of forest income and the contribution of primary forest products to each forest use strategy choice. The chi-square (X2) shows statistically different forest incomes in at least two clusters. For example, a forest income in Cluster One is statistically different from Cluster Two and Cluster Three and vice versa. The ANOVA test also reveals cluster income differences. For example, the total unprocessed forest income of Cluster One differs significantly from Cluster Two and Cluster Three (Table 7). Generally, the variance in the forest use strategy choices depended on whether the household was subsistence or cash-orientated. Subsistence-orientated forest users collected and used mainly firewood and forest foods; these were less remunerative activities, while charcoal was the most remunerative activity (Table 4).

Table 7.

Cluster Analysis for Forest Use Strategy Choices

Variables	Whole sample (n=412)	Clusters			X^2
		Pure subsistence forest users (1) (n=204)	Specialised charcoal sellers (2) (n=133)	Forest food and charcoal sellers(3) (n=75)	
[Y]**Absolute forest income**	3216±8833	$745^{2,3***}$ ±940	5784^{1***3} ±13840	5386^{1***2} ±7469	782^{***}
Unprocessed forest products income					
Total income	994±1259	$745^{2,3***}$ ±940	1239^{1***3} ±1378	1237^{1***2} ±1628	42^{***}
Subsistence income	916±1187	678^{2***3*} ±861	1239^{1***3} ±1378	992^{1*2} ±1434	46^{***}
Cash income	78±275	67^{2*3***} ±290	0^{1*3***} ±0	$245^{1,2***}$ ±388	10^{***}
Processed forest products income					
Total income	2222±8272	$0^{2,3***}$ ±0	4545^{1***3} ±13241	4149^{1***2} ±6342	42^{***}
Subsistence income	148±621	$0^{2,3***}$ ±0	249^{1***3} ±844	373^{1***2} ±860	0
Cash income	2074±7801	$0^{2,3***}$ ±0	4296^{1***3} ±12545	3776^{1***2} ±5794	46^{***}

[Y] Income values are in net value in AEU per capita and measured in Zambian Kwacha (ZMW). ± is the standard deviation. Superscript numbers show statistically significant differences between each respective cluster with other clusters (ANOVA test); *** significant at 0.01, ** significant at 0.05, and * significant at 0.1 levels. Note the international poverty line for Zambia is considered to be less than 6.4 ZMW per day (World Bank, 2018).

4.2.2. Determinants of Households Forest Use Strategy Choices

The MNL regression results (Table 8) support the cluster analysis presented in Section 4.2.1., that households in the Miombo woodlands of the Copperbelt are pursuing different forest use strategy choices with respect to the capital available to them. The effects of independent variables on forest use strategy choices of households are analysed with the most common forest use strategy; pure subsistence forest users as the reference category (Table 7). The positive coefficients in the MNL regression (Table 8) thus indicate that the independent variables positively relate to the probability of being in the cluster concerned (i.e. Cluster Two or Cluster Three), while the negative ones support the reference category. For example, longer distances to public forestlands increase the likelihood of households belonging to Cluster Two and Three relative to Cluster One, while increasing distances from exclusively owned forestlands reduce the possibility of households belonging to Cluster Two and Three relative to Cluster One. Regarding the general fit of the model, the global chi-square, the associated p-value and R-square indicate that the model is significant (Table 8); this implies that independent variables in the model explain, to some extent, the variances observed in the forest use strategy choices.

Furthermore, the MNL results (Table 8) reveal different effects on each forest use strategy choice. However, both specialised charcoal sellers and forest food and charcoal sellers are affected by distances to public and exclusively owned forestlands and a lack of access to permanent roads. On the other hand, results show that households with a small household size are less likely to belong to Cluster Two compared to Cluster One. Similarly, households with ageing household heads are less likely to belong to Cluster Three relative to Cluster One. Adding to the salience of this analysis is the effect of increasing off-farm income on the likelihood of households belonging to Cluster Three relative to Cluster One (Table 8). Although the effect appears to be too small (i.e. 0.001 coefficient), this could be attributed, in part, to the high variance of rural income in the study area (Table 3).

We included landscape dummies in the model; whether the household belonged to a restricted or non-restricted landscape to control for spatial heterogeneity with Cluster One (pure subsistence-orientated forest user) as a base category, and the findings demonstrate that there is significant spatial variability. Compared to Cluster One, households in restricted landscapes are more likely to adopt forest food and charcoal sellers strategy, findings backed by the outcomes in Table 5, that the volume of forest products extracted from restricted landscapes was higher than that of non-restricted landscapes in the Copperbelt province.

Table 8

MNL Results for the Determinants of Households Forest Use Strategy Choices (Pure subsistence-orientated forest users (Cluster 1) as reference)

Variables	Coef. Std. Err.	
	Cluster 2 (Specialised charcoal sellers)	**Cluster 3 (Forest food and charcoal sellers)**
Natural capital		
Walking distance from household to public forestland (km)	0.344***(0.100)	0.389***(0.114)
Walking distance from household to private forestland (km)	-0.282***(0.107)	-0.341**(0.153)
Human capital		
Size of Household (number of adult equivalent)	-0.120*(0.072)	0.131(0.093)
Age of head of household (years)	0.007(0.009)	-0.026**(0.013)
Social capital		
Household belongs to the largest ethnic group (1-Lamba; 0-otherwise)	0.347(0.250)	0.248(0.317)
Duration of residence in the village (years)	-0.013(0.010)	0.007(0.012)
Financial capital		
Net income from off-farm (Kwacha)	0.000(0.001)	0.001*(0.001)
Physical capital		
Tropical livestock unit (current stock)	-0.027(0.036)	-0.103(0.058)
Land-size per adult equivalent (ha)	-0.031(0.044)	0.029(0.052)
Infrastructure (exogenous)		
Household had access to road usable throughout the year (yes-1, 0-otherwise)	-0.657**(0.271)	-0.760**(0.369)
Village dummy		
Restriction (village is in restricted arrangement-1, 0-otherwise)[a]	0.176(0.289)	1.159***(0.374)
Constant	-0.184(0.548)	-1.425**(0.717)
Number of observations = 412		
LR chi2 (22) = 99.80		
Prob > chi2 =0.000		
Log likelihood = -371.636		
Pseudo R2=0.118		

*** Significant at 0.01, ** significant at 0.05, *significant at 0.1; standard error in parenthesis. Multicollinearity was checked for by conducting a variance inflation factor (VIF). All the variables had less than 10 VIF. However, variables that showed p>0.5 in both Clusters 1 and 2 were removed from the model through manual backward stepwise elimination. [a]Dummy for village fixed effect.

5. Discussion

5.1. Main Characteristics of Households in the Study Area

As noted in Table 2, households in the rural Copperbelt province remained closer to exclusively owned forestlands relative to public forestlands and had an average of 2.3 hectares of land per AEU (the average size of a household is 4.5 persons in AEU (Table 2)). As reported elsewhere, about 60% of the households in Zambia use mainly hand-hoes for farming (Haggblade and Tembo, 2003). In highly populated provinces, such as the Copperbelt and Lusaka, it is estimated that households are able to cultivate pieces of land ranging from 1.38 to 3.5 hectares compared to other low populated provinces (0.25 ha per household) despite low labour productivity (CSO, 2012; Handavu et al., 2019; Mulenga et al., 2017; Shakacite et al., 2016). However, with the exception of areas lost due to slash and burn agriculture (Syampungani et al., 2016), arguably uncultivated forestland is used as a source of forest products to meet household food and cash needs (Jones et al., 2016; Kalaba et al., 2013b; Smith et al., 2017). Particularly as rural households live within exclusively owned forestlands which are characterised by mainly poor access to the permanent roads and markets (Table 2) (Dash et al., 2016). This finding suggests that areas that are highly populated clear more forestlands and are likely to use more forest products than areas with a low population (Ferretti-Gallon and Busch, 2014).

5.2. Description of Households Income Sources

In this study, forest product harvesting was found to be one of the most important income sources adopted by rural households in the Copperbelt province (Table 3). The share of forest income for both processed and unprocessed to the total household income was 54.1%. Our results agree with other studies that found that the contribution of forest products to household income was higher than that of most sources of rural income (Jumbe et al., 2008; Kalaba et al., 2013a; Mulenga et al., 2014), although variations were observed across studies. The differences across studies were likely due to the different scopes and context of the research. Jumbe et al. (2008), for instance, reported their findings based on eight sites in three provinces, while Kalaba et al. (2013a) observed their findings based on a study performed at two sites in the province of Copperbelt. Consequently, these discrepancies indicate that research still does not understand the economic significance of Zambia's forests, and this is an area for further study.

With regard to the contribution of specific forest products, our findings reveal that this varies depending on the products consumption form: processed or unprocessed (Table 4). Among processed products, charcoal was the main product with the largest share (37.4%) of total household income compared to other rural income sources (Table 3). Our result is confirmed in a study from Malawi by Smith et al. (2017), who observed that households were engaged in charcoal production because of the higher incomes associated with its production compared to other rural household sources (Jones et al., 2016; Kalaba et al., 2013b).

Forest products provide households with more subsistence and cash than any other income sources in the study area. Unprocessed forest products, such as firewood, forest foods, and structures and fibres (Table 4), contributed to 16.7% of the total household income and used for mostly subsistence purposes, findings corresponding to Mulenga et al. (2014), Kalaba et al. (2013a), and Hickey et al. (2016). However, our findings indicate a low use of forest products for medicinal purposes (Table 4), contrasting with results from previous studies that found higher use of medicinal plants in Zambia (Banda et al., 2007; Handavu et al., 2019; Ndubani and Höjer, 1999). The variations in study results are likely to reflect the methodology and context in which researchers performed their studies. For instance, Chinsembu (2016) documented the indigenous knowledge of medicinal plants among traditional healers, implying that knowledge on the use of medicinal plants is a reserve of traditional healers.

Similarly, Chungu et al. (2007), consulted traditional healers in studying the effects of bark removal for medicinal use. Their findings show that the use of medicinal plants is by a few knowledgeable people, referred to as “traditional healers”. Our study was not able to test whether households were producers of medicinal plants or preferred going to the traditional healers, but our results (Table 4) indicate that the economic value derived from the use of medicinal plants is low as compared to use of other forest products.

Our study further reveals that the types of forest products vary across rural households as a result of variances in the households’ capital (Ashley and Carney, 1999), household location (Ali and Rahut, 2018; Angelsen et al., 2014; Tugume et al., 2015), and the product season (Ellis, 2000). These factors may have caused the differences in the volumes of forest products collected. For example, we observe that the per capita production of charcoal and firewood extracted in restricted landscapes is higher than per capita volume of charcoal produced and firewood extracted in non-restricted landscapes, respectively (Table 5). These results correspond to Jagger et al. (2014) who in their global study, observed that households generate more forest income from state-owned forests than from private and community-owned forests.

5.3. Description of Households' Forest Use Strategy Choices

The cluster results conform to the descriptive characteristics of households in the Copperbelt (Table 3 and 4). Forest use strategies arise based on the capabilities of households and the various capitals at the households' disposition (Ashley and Carney, 1999; Scoones, 1998). Our findings reveal that rural households in the Miombo woodlands can be categorised into three forest use strategy choices with highly varying levels of income (Table 6). The cluster categories are specialised charcoal sellers (32.3%), forest food and charcoal sellers (18.2%), and pure subsistence-orientated forest users who constitute 49.5% of households.

Specialised charcoal sellers, and forest food and charcoal sellers (i.e. charcoal households) earned a higher total forest income (i.e. cash and subsistence forest income) compared to pure subsistence-orientated households. These findings are consistent with Mwitwa and Makano (2012) in Zambia, and Smith et al. (2017) in Malawi which observed that households participate in charcoal to generate income to meet one-off purchases of expensive items. This finding confirms the role of charcoal in meeting the income needs of households (Zorrilla-Miras et al., 2018), but also indicates that charcoal producing households are more affluent than pure subsistence-orientated forest users (Angelsen et al., 2014; Smith et al., 2017). With this logic, pure subsistence-orientated forest users are closely linked to poverty (World Bank, 2018), collecting mainly forest foods (Rowland et al., 2017), poles and fibres (Langat et al., 2016).

Furthermore, our study categorises households based on their use of unprocessed and processed forest products to derive household subsistence and cash income needs. Categorising households enables policymakers to create policies particular to a target group, which leads to the development of effective, sustainable forest management strategies. Overall, 50.5% of rural households in the study area adopted charcoal strategies, these were specialised charcoal sellers, and forest food and charcoal sellers (Table 6). In the rural Copperbelt province, charcoal strategy choices were the most remunerative relative to subsistence-orientated strategy choice. This outcome is in agreement with other studies that participating in charcoal production can improve the income of rural households in Africa (Khundi et al., 2011; Smith et al., 2017; Zorrilla-Miras et al., 2018).

In terms of per capita production, the volume of charcoal produced and firewood extracted varied according to the restriction regime of the landscape in which the household belonged. Restricted forestlands generated higher per capita volumes of charcoal and firewood than non-restricted forestlands (Table 5); this implies that extraction rather takes place in restricted landscapes rather than in non-restricted landscapes (Tugume et al., 2015), but also suggests that restriction does not affect households' use of forest resources (Jagger et al., 2014). Our finding reveals the potential overlapping claims on forest resources and potential weakness in Zambia's forest policies (Kalaba, 2016; Kalaba et al., 2014). However, in terms of charcoal as a driver of forest degradation (Vinya et al., 2011), our finding is not surprising as other studies observed charcoal production as driving forest degradation in most countries in sub-Saharan Africa, and Zambia in particular (Handavu et al., 2019; Tembo et al., 2015; Zulu and Richardson, 2013). Given that we observed higher volumes in restricted landscapes, restriction, therefore, does not generally affect household reporting of forest products, but our findings imply that restricted landscapes are more intensively used than non-restricted landscapes.

With regard to per capita consumption for charcoal, we found 447.29 kg/year (4.03m^3/year/AEU), and 269.51 kg/year (2.43m^3/year/AEU) in restricted and non-restricted landscapes respectively, which is identical to results observed in rural and urban Kenya 287kg/year, and 394kg/year, respectively (Kituyi et al., 2001); and Myanmar (280kg/year) (Win et al., 2018) respectively. For per capita consumption of firewood, our findings were lower (i.e. 709.93kg/year (0.23m^3/year/AEU), and 661 kg/year (0.22m^3/year/AEU)) in restricted and non-restricted landscapes respectively, but closer to the results in the previous studies. For example, in Myanmar, the per-household firewood consumption was 780 kgs/year (Win et al., 2018), in Kenya 780 kg/year, and Cambodia 760 kg/year (Top et al., 2003). The lower consumption of firewood in our study compared to the past studies could be attributed to the large household size in our study sites, 5.9 persons/household (4.5 AEU), compared to Kenya 5.5 person/household (Kituyi et al., 2001), and Myanmar 5.1 person/household (Win et al., 2018). Our finding is supported by the previous studies that found per capita consumption rates decrease exponentially with increasing household size, thus implying larger households are more efficient users of fuelwood than small ones (Kituyi et al., 2001).

5.4. Factors Determining Households' Forest Use Strategy Choices

Our analysis reveals the key capitals that influence households' forest use strategy choices in the Copperbelt province of Zambia are; natural, human, and financial (Table 8). Further providing evidence that households pursue different forest use strategies in accordance with the livelihood capitals at their disposition. The differences in household capital lead to differing forest use strategy choices among households, corresponding with Nguyen et al. (2015), and Babulo et al. (2008) who analysed livelihoods in Cambodia and Ethiopia, respectively.

Our study found that people who live closer to the public forestlands and had access to the forests were more likely to be in Cluster One (pure subsistence-orientated forests users). In contrast, we found charcoal producers (Cluster Two and Cluster Three) to be located further from public forestlands but closer to the exclusively owned forestlands, which corresponds with previous studies (Top et al., 2003; Win et al., 2018), indicating that access to woodfuel results in higher consumption rates. While our findings only relate to distances from forestlands, it demonstrates that forests owned exclusively are more susceptible to forest degradation than public forestlands. These findings are notable given that past studies to have often shown that secure tenure rights are linked to sustainable forest use (Andersson et al., 2018; Larson et al., 2010; Shi et al., 2016; Stickler et al., 2017). Thus, in this context, we suggest that assured ownership, particularly in traditional forest areas, does not necessarily solve the challenges of sustainable forest management on its own, in agreement with Lambini and Nguyen (2014), who compared the impact of institutional rights on forest livelihoods in Ghana and Vietnam and observed high levels of unsustainable exploitation in adjacent forest communities. Our findings further confirm that participation in charcoal production is greatest where households are located closer to the roads (Khundi et al., 2011; Mushtaq et al., 2014; Win et al., 2018).

For household capital, despite relatively high population growth in Copperbelt (CSO, 2012), our findings for household size and age of the household head are consistently negative and significant for charcoal households (Clusters Two and Cluster Three) (Fox, 1984; Kituyi et al., 2001; Win et al., 2018). For example, the collection of forest products in rural Copperbelt province is mainly linked to the household ability and cash needs (Handavu et al., 2019; Kalaba et al., 2013a; Tembo et al., 2015). Thus applying this logic, one is inclined to suggest that larger sized households are associated with low income in the rural areas of the Copperbelt because a household with a large membership has a broader option for other livelihood strategies. For the age of the household head, our findings suggest that households with relatively older heads are less likely to participate in the production of charcoal and, if they do, they are still unlikely to specialise in charcoal production (Khundi et al., 2011; Mulenga et al., 2014).

In addition, our findings indicate that off-farm income positively improves the probability of households belonging to the forest food and charcoal seller cluster (Cluster Three). While Cluster Three households are also involved in the production of charcoal, they have a comparatively reduced income when compared to the specialised charcoal sellers (Cluster Two). Yet Cluster Three still have higher incomes than the pure subsistence-orientated forest users, which means that off-farm activity reduces participation in the production of charcoal while subsistence activity rises. These findings are in agreement with (Mulenga et al., 2017; Nguyen et al., 2015), who observed that increasing off-farm activity is likely to reduce participation in charcoal production as rural households are less likely to engage in relatively resource-intensive activities.

Although we found higher forest product extraction in restricted landscapes compared to non-restricted landscapes (Table 5), restriction of forest resource use significantly influenced strategic forest use choices (Table 8). Belonging to a restricted landscape significantly increased the likelihood of households belonging to Cluster Three (only 18.2% of the households) compared to Cluster One (49.5% of the households). These findings indicate that the use of forest products in forested landscapes is culturally intertwined with people's livelihoods (Angelsen et al., 2014; Chidumayo and Gumbo, 2010; Handavu et al., 2019; Mulenga et al., 2014), and restrictions on the use of forest products have little or no effect on domestic extractive patterns (Naughton-Treves et al., 2007; Syampungani et al., 2016).

6. Conclusions and Policy Implications

Forest products are essential livelihood strategy choices for rural households in forested landscapes. Our study shows that the share of forest income in the province of Copperbelt is 54.1% and higher than any rural income source. However, other studies in Zambia found that forests account for about 22-44% of rural household income (Jumbe et al., 2008; Kalaba et al., 2013a; Mulenga et al., 2014). Such variability in findings shows that the economic importance of forests to Zambia's people is not yet adequately understood, and researchers and policymakers need more effort to gain a better understanding of the forests of Zambia.

Our study also shows that households in the province of Copperbelt of Zambia follow three distinct forest use strategies, which include pure subsistence-orientated forest users, specialised charcoal sellers, and forest food and charcoal sellers. Participation in charcoal production is associated with high income and accounts for about 50.5% of households in our study area; however, only one-third of households in the study area are involved in specialised charcoal production. As a result, we can conclude that charcoal production is a highly remunerative rural livelihood strategy, although with relatively high resource demands.

This study demonstrates that the producers of charcoal lived closer to exclusively owned forestlands than to public forestlands. The findings in this study, however, relate only to distances from forestlands, and they indicate that forestlands owned exclusively are more vulnerable to forest degradation, but we have not yet tested this hypothesis. Careful estimates (Table 5) indicate that most forest pressures are associated with the production of charcoal as the basis of cash income in rural areas. It is important to note that this study focus does not permit conclusions on whether forest use strategies implemented by households have a critical effect on forest losses. Nevertheless, if all households were to adopt the production of charcoal as a source of cash income, Miombo Woodland's productive capacity could be exceeded, eventually leading to unsustainable use that would impact both subsistence and commercial forest users.

Considering that rural households in the Copperbelt province adopted three strategic forest use choices, with varying income levels, we propose that characterising households based on forest product use is critical to understanding local livelihoods, providing a more nuanced perspective of the linkages between people and forest landscapes. In this regard, we suggest that policymakers and conservationists adopt approaches that consider the subsistence and charcoal needs of households. This can be achieved by introducing coppicing or reforestation systems that are consistent with the growing demands of Miombo, promoting sustainable forest product extraction, including charcoal production. Otherwise, overharvesting by charcoal producers' could further threaten subsistence-orientated household's livelihoods. Future studies should focus on understanding macro-level factors that drive forest loss, but not lose sight of the micro-level features and the choices made by individual households.

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Appendix A.

Table A1.

Definition of the Independent Variables used in the Regression Models

Variable	Definition	Unit	Literature
Natural capital			
Distance to forestland (public)	Distance from household to the public forestland	km	Nguyen et al. (2015); Ali and Rahut (2018); Tugume et al. (2015)
Distance to forestland (exclusively-owned)	The distance that household walk to exclusively-owned land	km	Khundi et al. (2011); Dash et al. (2016)
Forest-cover loss	Households report to have observed forest-cover loss over the last five years in the village (dummy 1= yes/0= no)	1/0	
Human capital			
Age	Age of head of the household	Years	Ali and Rahut (2018); Angelsen et al. (2014)
Gender	Male-headed household (dummy 1=male/0= female)	1/0	Pouliot and Treue (2013); Sunderland et al. (2014)
Household-size*	Household-size, adult equivalent	AEU	Ali and Rahut (2018); Angelsen et al. (2014); Dehghani Pour et al. (2018)
Education	Head of household attained high-school level and higher levels (dummy 1=high school and higher levels /0=otherwise)	1/0	Kamanga et al. (2009); Nakakaawa et al. (2015)
Social capital			
Ethnicity	Household belongs to a major ethnic group, (1 = Lamba, 0 = other tribes)	1/0	Adhikari et al. (2004); Kar and Jacobson (2012); (Torres et al., 2018)
Mobile phones	Number of mobile phones	number	Hartje and Hübler (2015); Nguyen et al. (2015)
Duration of residence	Years household lived in the village	years	Jumbe and Angelsen (2007)
Financial capital			
Access to credit	Household members had access to credit in the last 12 months (dummy 1=yes/0=otherwise)	1/0	Torres et al. (2018); Barrett et al. (2001)
Crop income**	Household-earned from crop	Kwacha /AEU	Kamanga et al. (2009); Mulenga et al. (2017)

Off-farm income	Household-earned income from off-farm	Kwacha /AEU	Mulenga et al. (2017)
Self-employment	Household-earned income from self-employment	Kwacha /AEU	
Total remittances* **	Household-earned income from remittances	Kwacha /AEU	Nguyen et al. (2015)
Wages	Household-earned wages	Kwacha /AEU	
Physical capital			
Livestock	Tropical livestock unit (TLU)-(stock)	number	Soltani et al. (2012)
Land owned	Land owned by household per AEU	Ha/AEU	Torres et al. (2018); Ali and Rahut (2018); Mulenga et al. (2017); Stickler et al. (2017); Andersson et al. (2018); Larson et al. (2010); Shi et al. (2016)
Infrastructure (exogenous)			
Access to the road network	Household reports to have at least access to a road useable by car throughout the year (paved or gravel) (dummy 1=paved/0=otherwise)	1/0	Jansen et al. (2006); Soltani et al. (2012); Babulo et al. (2008)
Distance to the main road	Distance to the main road	km	Babigumira et al. (2014)
Vulnerability context (exogenous)			
Income shock - Crop failure	Household reports having experienced serious crop failure in the past 12 months (dummy 1=yes/0=otherwise)	1/0	Angelsen et al. (2014); Babigumira et al. (2014)
Asset shock - Livestock loss	Household reports having experienced serious livestock loss in the past 12 months (dummy 1=yes/0=otherwise)	1/0	
Labour shock - Serious Illness/death of a family member	Household reports having experienced illness of family member in the past 12 months (dummy 1=yes/0=otherwise)	1/0	

*Adult equivalent (AEU) as applied by Dokken and Angelsen (2015) where adults aged between 15-64 are assigned a weight of one (1), and dependents below 15 and above 64 are assigned a weight of 0.5. ** Income is measured in Zambian Kwacha (ZMW). *** Remittances include monetary transfers from government, community support or household members working in another location (internal or abroad).

Determining the Optimal K-means for Cluster

We performed k-means cluster algorithm using R Version 3.5.3., on data collected from the household survey conducted between 2017 and 2018 in Zambia. To determine the optimal number of clusters for our cluster analysis, we followed procedures as prescribed by Makles (2012). We compared several k-means with a different number of groups. The optimal k-means was three clusters which we zeroed at after observing the kink in Fig. A1.

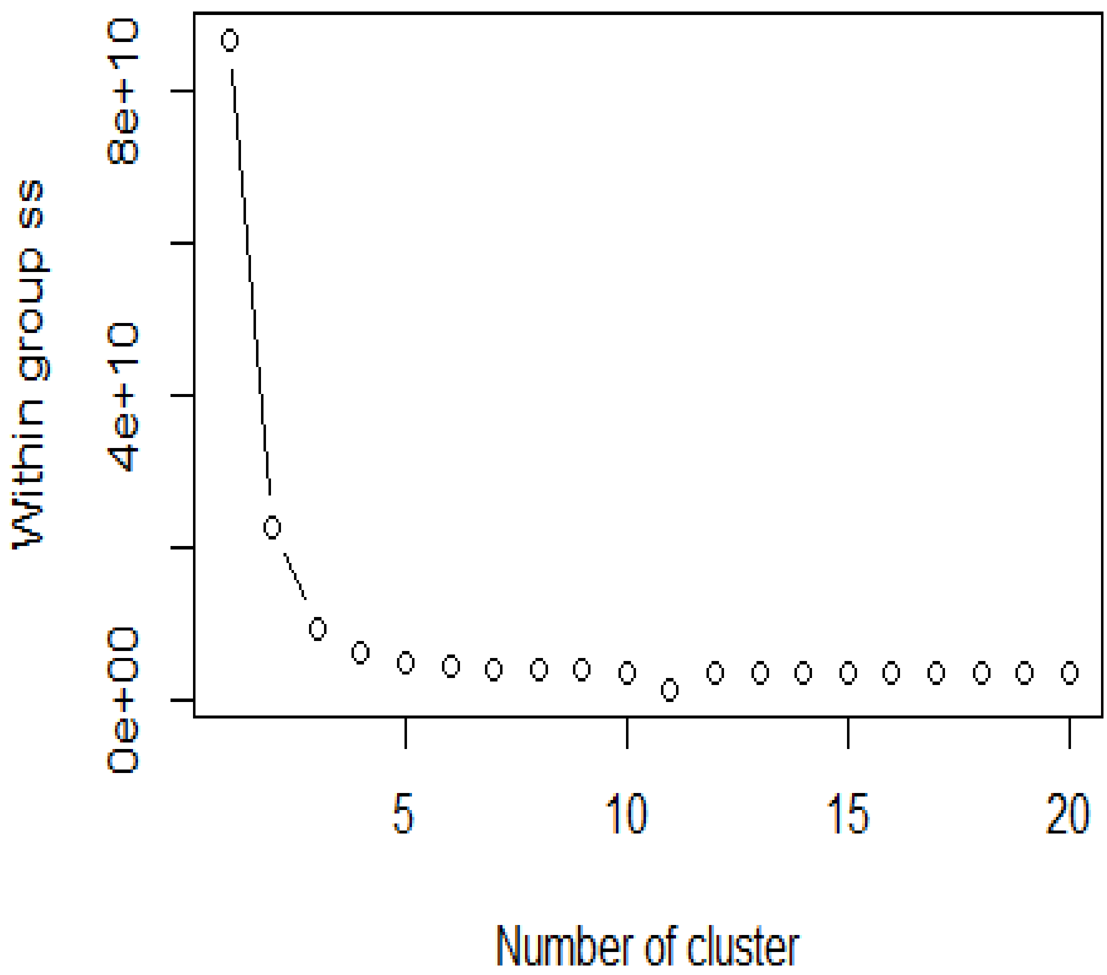

Fig. A1. The scree plot shows the kink for optimal k-means clustering.

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